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Office of Naval Research

Grant Final Report

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Contract/Grant Number: N00014-93-1-0195

Scientific Officer: George B. Wright, Electronics Division

Contract/Grant Period: 01 March 1993 through 28 Feb 1994

Contract/Grant Title: "Low Energy Ion Beam Assisted Growth of Homoepitaxial Silicon Films at Low Temperature"

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*Note this grant comes under the program: Support of Post-Tenure Research by NRC-NRL/NOARL Research Associates (one year $50,000 grant)

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Publications: One paper has been completed and submitted for publication in the **Journal of Nuclear Instruments and Methods B**. The title is:
"Total Sputtering Yield of Ag/Cu Alloys For Low Energy Argon Ions":
K.W. Pierson, J.L. Reeves, T.D.Krueger
Dept. of Physics and Astronomy, University of Wisconsin - Eau Claire
C.B. Cooper
Department of Physics and Astronomy, University of Delaware

This paper documents the unique capabilities of the low energy ion source which is integral to the low temperature epitaxial growth technique being investigated.

Note, two undergraduate physics majors are included as authors on this paper.

Presentations: (1) 8th National Conference on Undergraduate Research, April 14-16, 1994, "Effect of Grain Size on the Sputtering Yield of Ag/Cu Two-Phase Alloys": Terrence D. Krueger, Jody L. Reeves, Robert J. Brunson, Kim W. Pierson, Department of Physics and Astronomy, University of Wisconsin - Eau Claire

(2) 2nd Annual Student Research Day Poster Session May 4-5, 1994 "Effect of Grain Size on the Sputtering Yield of Ag/Cu Two-Phase Alloys": Terrence D. Krueger, Jody L. Reeves, Robert J. Brunson, Kim W. Pierson, Department of Physics and Astronomy, University of Wisconsin - Eau Claire

(3) Annual Spring Meeting of the American Vacuum Society Illinois Chapter at Northwestern University, April 29,1994 "Anomalous Sputtering Yield of Ag/Cu Alloys for Low Energy Argon Ions" K.W. Pierson, J.L. Reeves, T.D. Krueger, R.J. Brunson, Department of Physics and Astronomy, University of Wisconsin - Eau Claire (submitted for acceptance on April 4 1994)

(4) Undergraduate Research Forum, St. Cloud State University, MN May 6 - 7, 1994, "Total Sputtering Yield of Ag/Cu Alloys For Low Energy Argon Ions": Terrence D. Krueger, Jody L. Reeves, Robert J. Brunson, Kim W. Pierson, Department of Physics and Astronomy, University of Wisconsin - Eau Claire

* J.L. Reeves, T.D. Krueger, and R.J. Brunson are undergraduates

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Final Technical Report:

Low Energy Ion Beam Assisted Growth of Homoepitaxial Silicon Films at Low Substrate Temperatures

Summary of Original Scientific Proposal:

The goal of this project was to lower the substrate temperature required to promote device quality epitaxial silicon growth below the 300°C mark set by a Japanese group led by T. Ohmi (see references 10,12,13,14 of original proposal). Normally high substrate temperatures are required to achieve thin film epitaxial growth. A new thin film deposition technique called ion beam assisted deposition offers the possibility to grow epitaxial layers at low substrate temperatures. In this technique, while the atoms are condensing into the epilayer, they are bombarded by low energy noble gas ions. The kinetic energy of the incident ions supplants the thermal energy lost by lowering the substrate temperature and provides enough surface mobility so that the correct crystal structure can grow. Lower temperatures will reduce impurity and interlayer diffusion problems caused by high temperature growth processing steps.

In order to lower the epitaxial temperature further, the condensing surface atoms need greater bombardment induced mobility to ensure that they have enough energy to migrate and find the proper lattice position. The previous work of the Japanese group suggests that the key to lowering the epitaxial temperature is to find the optimum incident energy that promotes epitaxial growth and then increase the current density. While this is a logical conclusion and has been recognized by the Japanese group, what does not appear to have been appreciated is the connection this work has to that of R.S. Robinson and S.M. Rossnagel (reference 18 of original proposal) concerning ion-beam induced topography and surface diffusion. Robinson and Rossnagel were able to show that during ion bombardment the irradiation induced mobility of surface atoms (surface diffusion) scales as the **square** of the incident ion current density. Thus a small increase in ion flux will result in a substantial increase in ion induced surface mobility. This large increase in mobility will allow device quality epitaxial growth to occur at lower substrate temperatures.Since thermal diffusion scales exponentially with temperature, a small decrease in the substrate temperature will provide a tremendous decrease in device degrading thermal diffusion.

I have extensive experience with a unique low energy ion source that can provide much greater current densities than the sources used by the Japanese group. At 25 eV this source can provide a current density of 10 mA/cm^2, while the ion source used by the Japanese group generated only 2.3 mA/cm^2. Given the discussion of the previous paragraph this implies an order of magnitude increase in ion induced surface mobility and indicates that the substrate temperature required for epitaxial growth can be lowered below 300°C.

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Work Completed to Date:

I am a new faculty member in the Physics Department at the University of Wisconsin - Eau Claire (UWEC). UWEC is an undergraduate university.

This project required the design and construction of an Ultra-High Vacuum (UHV) chamber. Unfortunately, due to the bidding procedure that must be followed to purchase capital equipment, the components necessary to construct the UHV chamber did not arrive until late in July 1993 (grant began in March). While waiting for the components to arrive, I worked with two students (funded over the summer by the University) on the construction of a High Vacuum (HV) chamber to test the design of the ion source that will be used in the low temperature ion assisted growth studies. We used equipment donated by both my graduate school adviser and my post-doc advisor at NRL. The HV chamber was completed during the summer and testing began on the ion source. The source is a modification of a design I worked with extensively during my graduate studies. The ion source is now working properly and a sputtering experiment was performed during the 93-94 school year to document its capabilities. A paper concerning that work has been submitted for publication. Also during the 93-94 school year construction of the UHV chamber has been underway. After that chamber is completed during the summer of 94, experiments on the low temperature ion assisted growth technique will begin.

* Note *

The semester teaching load in the physics department at UWEC consists of lecturing 2 courses (3 to 4 lectures per week per course) along with 2 to 3 laboratory sections (4-6 hours per week). This leaves approximately 12 hours per work week and 8 hours on Saturday for research during the regular semester. I have no teaching commitments during the summers.